An overview of systems modelling and evaluation tendencies

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RESUME

Dans ce papier nous présentons une synthèse des travaux de recherche récents et des tendances dans le domaine de la modélisation et de l'évaluation de performances de systèmes informatiques et des réseaux et ordinateurs. Cette étude inclut les problèmes de modélisation posés par les nouveaux systèmes répartis.

ABSTRACT

This paper concerns the area of modelling and evaluation of computer systems, computer networks and distributed systems. What are the main publications and orientations in this domain and what are the new modelling problems involved by the evovution of computer science (especially by the architecture of new systems)?.

I . INTRODUCTION

During the last ten years a lot of papers about modeling and performance evaluation of computer systems and computer networks have been published. Now new distributed systems are being built, integrating computers and communications. This involves new modeling and evaluation problems. The goal of this paper is to present the main developments and trends in this domain.

II. MODELING AND PERFORMANCE EVALUATION OF COMPUTER SYSTEMS

On Figure 1 we show the different steps needed to evaluate a system, and two ways to procede.

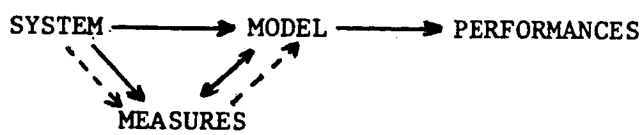

Fig.1

In the first one (solid arrows) a model is deduced from the system. The model is used to determine parameters which are measured or estimated from the system. There the measures are integrated in the model to obtain performances which are supposed to be representative of the system. An illustration of this procedure is the modelling of computer networks or computer systems (or part of them as central [Cour 77, Jomi 81] or secondary memory [Ge Mi 80, Bran 81, Arti 81] management etc...) using queues and queueing networks [Klei 76] scheduling models [Coff 76] or Petri nets [Zube 81, Br FN 82].

In the second case (dashed arrows) empirical models are deduced from measures [Ferr 78, Svob 76, Fe Sp 80], using statistical techniques like regression, multidimensional analysis [Rala 79] chronological series, etc... They are mainly used in the study of systems workload.

In this part we will concentrate on computer systems modeling using queueing networks because this approach has been very successful and has produced a lot of important results. We begin by the fundamental theorem of Basket Chandy Muntz and Palacios [BCMP 75] which characterizes queueing networks with "product form solution". This means that these networks of queues with n nodes possess a steady state probability distribution P_s of the network state s of the form :

$$P_s = d.\ f(s).\ \prod_{i=1}^{n} P_{s(i)} \qquad (1)$$

where d is a normalizing constant, $P_{s(i)}$ is the steady state probability of the corresponding state s(i) of the queueing system in the node i, and f(s) is a function of the number of customers depending on the state s [Ja Ko 80].

Two complementary approaches are developed to extend this type of solution to other networks. In the first one it is shown that some particular queueing networks admit product form solution. A.Hordijk and N.Van Dijk use it, for instance in [Ho VD 81] for certain cases of exponential queueing networks with blocking. We find it too in [Ja Ko 80] where U.Jansen and D.Konig use insensitivity properties to characterize an important family of open, closed or mixed networks admitting product form steady state probabilities. These results are based on the complementary approach in which more powerful new mathematical tools are developed. The outstanding works in this area have been made by Kelly [Kell 79] on reversibility and quasi-reversibility, and by Schassberger [Scha 77, He Sc 79] on insensitivity, connected with the last developments on point processes theory. A synthesis of this theory based on Palm's measure is presented, in [FKAS 79] by Franken, Kônig , Arndt and Schmidt.

Due to the large number of states in the system, the computation of the normalization constant d in (1) may be untractable for real networks. As a result some computational algorithms have been presented by Chandy and Sauer [ChSa 80] and by Bruell and Balbo [BrBa 80]. Other algorithms, possibly approximate, for large networks have been proposed by Mackenna and Mitra [MKMi 81] and Lavenberg [Lave 80]. Approaching it another way, for product form solution networks it is possible to directly obtain some parameters, thereby avoiding the normalization constant computation by the use of "mean value analysis" [ReLa 80].

The product form solutions [Pujo 80] are connected with an idea of "independence" between the different queues. This does not happen in some cases of computer systems or computer networks modelling which involve dependencies between queues. The exact analytical solution for some of these problems has been established, for instance, when it is possible to come to bidimensional markovian processus models [FaKM 80] and for a particular case of two coupled queues networks [Fayo 79].

However, at the present, in most cases the practical solution of such systems may be studied using :

1) numerical techniques [Stew 79, KiMi 80]
2) approximations of the model by decomposition and equivalence [Bran 80] or by decomposability-aggregation [Cour 77, VaGL 80]
3) or approximate solutions of the model by diffusion method [Koba 78], or isolation [LaPu 80], or by iterative techniques [DoAS 81, Mari 78].

Different methods may be used simultaneously.

Some packages providing the facility of describing and solving (with exact or approximate methods) queueing networks have been developed, such as QNAP at INRIA [PoVe 79], QMOD [Gron 81], RESQ and QNET4 at IBM [ReSa 78, SaMS 80]. Among other solution techniques QNAP and RESQ offer the possibility of obtaining results using simulation.

To satisfy the needs of performance evaluation, important improvements in simulation [Lero 80, BaSa 81] have occurred. The latest deal with

1) the simulation inputs : how to build random numbers generators, and how to generate correlated number sequences [Bade 79]
2) the analysis of the simulator outputs : a lot of papers have been published on the regenerative method [IgSh 80, Igle 78, LaMS 79] and on the confidence interval accuracy [HeWe 81].

III. MODELING AND PERFORMANCE EVALUATION OF COMPUTER NETWORKS

The same tools are often used in computer systems and computer networks modeling, so its is difficult to draw a clear (and artificial) boundary between them.

The use of queueing networks to model computer networks is widespread. The importance of priorities, blocking (e.g. due to the limited size of buffers), the possible packet desequencing, etc., often need the use of approximate solutions or simulation, they can be used only when the number of system states is rather small. As a result other modeling techniques are used [TGPM 78] such as the stochastic processes theory (renewal theory, Markov chains, semi-markov processes, regenerative processes) and the markovian theory of decision.

M. Reiser, in a very interesting report [Reis 81], classifies the performance evaluation studies of data communication systems into four categories, (the first one being the most numerous) :

1) evaluation of a given protocol
2) design and configuration of real networks
3) performance evaluation of "products" (packets) of communication networks
4) performance evaluation of real networks based on their "products" and on workload measures.

It appears that the recent improvements in the performance evaluation of general networks have occurred in the modeling phase (transition from model to the expression of performance). The most important aspect in this approach has been the structuring of protocols into layers (7 for ISO) and their normalization [SRWG 80, ISO, PoZi 78, ZiPo 81] Such structuring has been very useful in understanding their functionning and, as a result, in modeling them. Thus there are now results on the performance evaluation of different level protocols, such as HDLC (layer 2) [Sere 81, LaPu 79] or of a set of layers such as X.25 (CCITT) [GiJM 81] which integrates the three lowest layers. A special attention must be given to the interrelationship between the different level protocols [BuSc 81].

For the local networks the normalization is in progress, and the situation is characterized by a very wide variety of supports (and, as a consequence of theoretical throughput), topologies and access protocols.

A taxonomy and comparison of random access protocols for computer networks have been proposed in [Mi Na 81]. Fixed and dynamic schemes are distinguished, and for the dynamic one they are separated in centralized, centralized polling, contention networks and decentralized. A new distinction is made in the decentralized dynamic assignation schemes between the random access (different types of ALOHA and CSMA) and the non-random access (decentralized reservation, polling, round robin, alternating priorities, random order, minislotted). Many papers have been published on that subject : references and protocol comparisons may be found in [Reis 81, Mina 81, Bux 81], and studies on particular protocols in [To Hu 80, Ge Mi 81, Span 81].

Some special topics of networks gave rise to studies, such as the messages resequencing , a synthesis of which is in [Ba GP 81]. Yet, in other domains the emphasis is placed on feasability more than on performance evaluation : the network interconnection [ISCA 80, ISCA 81, PWIN 80, FaMi 81] is an example of situation where very few papers appear on performance evaluation [Bern81] despite a real need. New performance evaluation problems arise with the use of networks to transport not only data but voice or pictures, in applications like burotics (office automation) or telematics. These uses involve different constraints in quality, speed and volume of tranfered data.

IV . DISTRIBUTED SYSTEMS :

The evolution of technology particularly the miniaturization (microprocessors) and the communications development (buses, local networks), and the fall of hardware prices involves the development of distributed systems. Beyond the versatility of such systems the idea is to use some small cooperating machines to perform tasks formerly devoted to large centralized systems [QED 78].

Therefore new systems oriented toward applications (like office automation, robotics, computer assisted instruction) are created. They are completely different form the universal centralized systems of the preceding generation.

These new distributed systems are sets of processors, specialized (like data bases machines) or universal, tightly coupled by buses or loosely coupled by network (especially local network). In an application it is possible to distribute the computation and / or the data, and / or the control. For each of these cases a great variety of choices is possible in distributing and in managing the distribution.

The diversity of distribution choices is superimposed on the diversity of applications. The performance evaluation must take into account these two aspects : thus in a distributed system every site requires the application software and the modules necessary to manage the communications and the distribution. The different parts of the software are in conflict for access to some ressources of the system (memory and computation time). This has an impact on performance, particularly when synchronization between processes involves forced idleness of some processors.

As a result the studies on modeling and performance evaluation evolve along two axises : the evaluation of specific applications and the evaluation of the distribution.

The evaluation of applications poses the problem of the generality of the studied applications. Also numerous papers published on this subject are devoted to data base management systems (DBMS) because they are widespread and increasingly used in the heart of new systems [DWHa 81, Tsic 81]. They take an interest in the DBMS as a whole [Sevc 81, LoMa 81, HeWY 81] or in some specific point such as the concurency control [RiSt 77 ShSp 81, Ries 81, ChGM 81, PoLe 80], the access paths to data [AsKS 80], and, when the relational model is used, the size of operations results [GeGa 82, Rich 80] and the query optimization [Kim 81] etc. The large variety of types of DBMS is an obstacle their modeling.

The quantitative evaluation of distributed systems is limited by lack of tools to model the synchronization. However evaluation studies are published on tightly connected architectures [Pate 81, BaWS 80, Gele 80, GrPa 80] and on loosley connected ones [BaFl 80] with a particular interest for distributed data bases [CoGP 80, Garc 79, Wilm 79]. Those papers are mainly based on theoretical algorithms to manage distributed systems and not on existing systems. Thus the count of messages necessary for the correct execution of a two phase commit in a distributed data base is interesting to compare different algorithms for maintaining concurrency [Wilm 79] but it is clearly insufficient to determine the intririsic performance of one particular algorithm. But in [Garc 79] we find analytic models and simulations for some of these algorithmes. So a lot of work is to be done to obtain a clear idea of distributed system performance. This will be possible with the implementation of systems and the development of experimental concrete models [BCEJK81] which will point out the crucial performance problems by measures.

V. CONCLUSION

In the course of this study we have seen how the theoreticians began with the modeling of computer systems and computer networks using queueing networks, and how they were obliged to improve more and more their mathematical tools. Simultaneously the evolution of technology and the creation of systems of increasing complexity, integrating processors and communications, raised new problems necessitating the development of new modeling tools. Many problem problems are still open in these different areas.

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